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Inner structure of capital control networks

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Abstract

We study the topological structure of the network of shareholding relationships in the Italian stock market (MIB) and in two US stock markets (NYSE and NASDAQ). The portfolio diversification and the wealth invested on the market by economical agents have been shown in our previous work to have all a power law behavior. However, a further investigation shows that the inner structure of the capital control network are not at all the same across markets. The shareholding network is a weighted graph, therefore we introduce two quantities analogous to in-degree and out-degree for weighted graphs which measure, respectively: the number of effective shareholders of a stock and the number of companies effectively controlled by a single holder. Combining the information carried by the distributions of these two quantities we are able to extract the backbone of each market and we find that while the MIB splits into several separated groups of interest, the US markets is characterized by very large holders sharing control on overlapping subsets of stocks. This method seems promising for the analysis of the topology of capital control networks in general and not only in the stock market.

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Keywords: Shareholding; Financial; Network; Weighted graph

1. Introduction

Despite the fact that the topology of a network is known to play a major role in robustness against shocks, no systematic statistical investigation of the topological properties of the ownership networks in the stock markets have yet been carried out. Most empirical studies of complex networks in financial systems have focused on wealth

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distribution [1], on asset return correlations [2,3], and on the network of corporate boards and directors [4]. A comparative study of the topological properties of the latter networks has been done in Ref. [5], while the issue of how the topology of board interlock can affect the decision making process of the board directors has been addressed in Ref. [6] in the case of local decision and in Ref. [7] in the case of global decisions. Few works about ownership networks in the literature have focused essentially on the analysis of their small world properties [8,9].

We have collected the data of the Shareholding Network (SN) as it appeared in 2002 in two US stock market (New York Stock Exchange (NYSE) and National Association of Securities Dealers Automatic Quotations Systems (NASDAQ), [1]) and in one European stock market (MIB, [10]). We have performed a systematic study of the topological properties of such networks using a complex networks approach [11], with particular attention at edges weights [12]. In a previous paper [13] we have addressed the issue of whether it is possible to classify stock markets based on the scale free nature of the connectivity properties. In [14] we have investigated the inner organization of such networks addressing issues such as:

1. how small is the subset of "super-investors" that controls the major part of a market;
2. how such "super-investors" share out the market among themselves (whether each one controls different companies or if instead they control the same companies);
3. how ownership concentration of stocks is distributed and how it is correlated with the market value of the stock and with the power that investors have globally on the market.

The set of companies quoted on a stock market, together with their respective top-holders form the Shareholding Network (SN). To represent the shareholding relationships between companies and investors we defined a graph whose vertices represent either companies or shareholders (either another company or a mutual fund or an individual, hereafter we denote this as an economic "agent"). A link is drawn from the company to the shareholder, resulting in a directed graph. Each link is weighted by the fraction of shares held. We have performed a systematic study of the topological properties of the SN in 2002 for two US stockmarket (NYSE and NASDAQ) and one European stockmarket (Milan). Data for the Borsa Valori di Milano (MIB) are publicly available in form of report [10], while in the case of the US markets this information is available through the Web (see footnote 1). The stocks considered for the latter case are those traded in the NYSE and those traded in the NASDAQ.

2. The backbone of the network

We introduce two indexes that capture the fact that for instance, a 10% shareholder holds much more control if the other shareholders hold 1% each, than if they hold

[1] Single companies informations are available at http://finance.lycos.com.

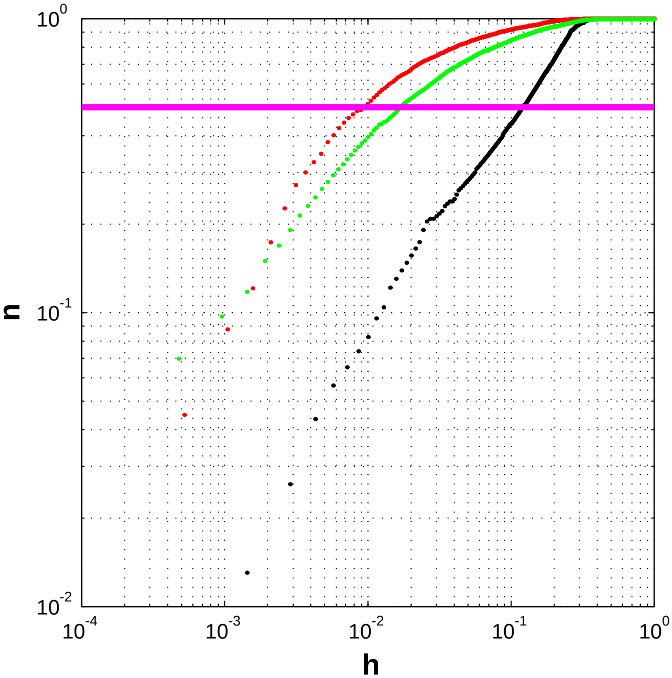

Fig. 1. Fraction of stocks n controlled by the fraction h of holders sorted by their power on the market (as measured by the HI index, see text). The three curves refer (from left to right) to NYSE, NASDAQ and MIB.

10% each.

$$SI = \frac{(\sum_{i \in holders} w_i)^2}{\sum_{i \in holders} w_i^2} . \tag{1}$$

Stock Index (SI) gives the effective number of holders controlling the stock. SI is close to 1 when there is a dominating holder. SI is equal to N when there are N equally important holders. For each holder j and each stock i we compute:

$$h = \frac{w_{ij}^2}{(\sum_{k \in holders} w_{ik})^2} . \tag{2}$$

Then for each holder we sum the above quantity for each of the stocks in his portfolio.

$$HI = \frac{\sum_{i \in stocks.owned.by.j} w_{ij}^2}{(\sum_{k \in holders.of.stock.i} w_{ik})^2} . \tag{3}$$

Holder Index (HI) gives the effective number of stocks controlled by a holder. HI and SI are analogous to k_{in} and k_{out} for a weighted network [12], because they measure the effective number of in-going and out-going links. The distributions of SI and HI are reported in Ref. [14]. It turns out that while in MIB companies are typically controlled by a single holder. In the US markets the large majority of companies is controlled

Fig. 2. The Italian Stock Market, MIB. From the subnetwork of 94 super-holders only the connected components of more than 4 nodes are shown. See the text for the extraction of the network from the original one. The network splits in trees corresponding to groups of interest.

by 6 holders. The distribution of HI has a power law behavior similarly to the k_{in} distribution [13].

We ask the following question: *is there a subset of holders controlling the market*? We answer this question in the following way. Consider the first h holders sorted by their value of HI, which is a measure of the power they have on the market. We count how many stocks are controlled with an effective weight of more than 0.5, by the union of the h holders (that is, we sum up the effective weights of all the h holders in the stocks). The set of stocks obtained in this way is a subset A of all stocks and the h holders collectively control completely (with more than 50%) each of the stocks in A. Now we vary h and we keep computing the relative size $\mathbf{n}$ of the subset A with respect to the entire set of stocks. We normalize h by the total number of holders, but we keep the name of this quantity, so that now $h \in [0\,1]$. We plot n as function of h in Fig. 1. Consider as a reference the value $\hat{h}$ such that $n = \frac{1}{2}$ (the horizontal line in the figure). This is the fraction of holders that control completely half of the stocks in the market, a simple quantity that we can use to characterize how much the control over the market is concentrated. We find: $\hat{h}_{mib} = 0.12$, $\hat{h}_{nys} = 0.94 \times 10^{-2}$, $\hat{h}_{nas} = 1.65 \times 10^{-2}$. It follows that in the US markets the control concentration is one order of magnitude higher than in the MIB.

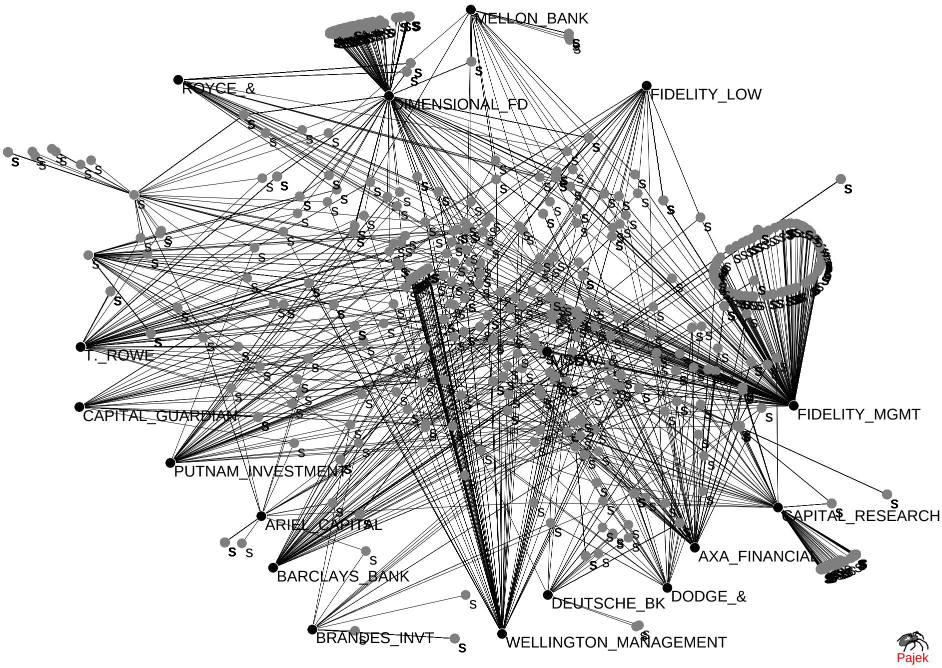

Fig. 3. The US Stock Market NYSE. Subnetwork of 24 super-holders. See the text for the extraction of the network from the original one. The network remains connected.

We want now to understand *how the super-holders share out the market among themselves*, namely whether: each holder controls a separate subset of stocks, or if super-holders' portfolios are largely overlapping or again if super-holders are divided in subgroups such that holders in the same group have overlapping portfolios, but different groups have non-overlapping portfolios. First we consider the network restricted to the super-holders of the market and to the stocks owned by the super-holders. Now, for each stock we keep only as many holders as the rounded value of SI. So for example if there are 5 holders but SI is close to 3, we keep only the three largest holders. We obtained a subnetwork of the original one, with the same number of nodes but with fewer edges as we have removed the weakest ones. We then perform a connected component analysis on the new network.

The result is that MIB is a forest of 89 separate trees (the presence of trees could be inferred from the fact that SI is typically 1). In Fig. 2 some of the connected component have been put in planar graph representation. Each tree reflects a group of interest or a family of owners. On the contrary NYSE is one single connected component. Still there could be some highly connected subnetworks in it. A graphical visualization (Fig. 3) of the subnetwork formed by the 24 super-holder of NYSE and by their stocks (1980 nodes in total) suggests that this is not the case. Nodes have been arranged in space in such a way that stocks controlled by a single holder are internal to polygon of the holders (green nodes). We checked out the existence of subgroups by computing a matrix of the portfolios overlap as described in Ref. [14]. Based on this method the super-holders in the US markets cannot be separated into subgroups, confirming the result obtained with the connected component analysis.

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